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16. Abstract

This report presents a synthesis of issues, strategies, and procedures with respect to traffic management for major emergencies. The intent of the report is to provide the reader with an overview of the various concerns surrounding emergency traffic management planning and operations, and to illustrate the necessity of planning efforts by an agency in order to be truly prepared for any type of emergency. Traffic management requirements for an emergency can vary dramatically from event to event, ranging from the use of standard traffic control procedures and devices during a relatively localized emergency to the implementation of highly innovative and controversial practices that may be necessary for a particularly devastating or widespread emergency. It is hoped that the examples and points made in the synthesis will stimulate discussion and evaluation within an agency as to how it may utilize these or other techniques should the need arise.

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SYNTHESIS OF TRAFFIC MANAGEMENT FOR MAJOR EMERGENCIES

by

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Research Report 1231-1
Research Study Number 2-18-90-1231

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January 1991

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in²	square inches	645.2	centimetres squared	cm²
ft²	square feet	0.0929	metres squared	m²
yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

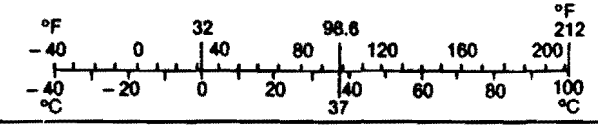
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm²	millimetres squared	0.0016	square inches	in²
m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas State Department of Highways or Public Transportation. This report does not constitute a standard, specification, or regulation.

SUMMARY

This report presents a synthesis of issues, strategies, and procedures surrounding traffic management for major emergencies. The intent of the report is to provide the reader with an overview of the various concerns surrounding emergency traffic management planning and operations, and to illustrate the necessity of planning efforts by an agency in order to be truly prepared for any type of emergency.

Chapter 1 presents an introduction to emergency traffic management. A distinction is made between different categories of emergencies. Two categories are defined, those where an agency can take a proactive approach, developing detail emergency management plans and standard operating procedures, and those where the agency must take a reactive approach, those situations that cannot be predicted or expected. Although planning regularly occurs for the former type of emergency, planning for reactionary emergencies is often ignored because of the feeling that nothing can be done to prepare for all types of emergencies. However, experiences across the nation indicate that planning can be performed and will significantly improve an agency's ability to respond to all types of emergencies.

Chapter 2 is an overview of the legal and legislative aspects of traffic management for major emergencies. The need for emergency readiness planning is mandated through federal and state laws. Several documents have been prepared outlining how emergency transportation planning and management is to be accomplished, and to define (in general terms) the roles and responsibilities of the state transportation agency. Again, experiences nationwide indicate that agencies need to do more. State and local agencies must begin to address the implications of their planning (or lack thereof) efforts for emergencies, as the umbrella protection of immunity laws continues to be challenged in the courts.

Chapter 3 summarizes the various traffic management elements for major emergencies that were identified through the literature review and contacts with federal, state, and local officials involved in emergency preparedness and transportation management. Three major phases of transportation management for major emergencies are presented:

- Advance Traffic Management Planning and Preparation,
- Traffic Management Activities During Emergency, and
- Traffic Management Activities for Emergency Recovery.

Several ingredients of successful advance planning and preparations have been identified. These include:

- Developing interagency and intraagency agreements;
- Developing personnel and equipment resource lists within an agency and pooling those of several agencies in order to prepare for emergencies of a regional magnitude;
- Developing and keeping current estimates of potential

problems or strengths of the transportation network during times of emergency response and recovery; and
- Developing a strong communications system within the agency, between several agencies, and with the public.

A number of traffic management activities during an actual emergency were also identified. These can be categorized along the following lines:

- Traffic control devices and signing,
- Active traffic control and management,
- Emergency efforts to increase roadway capacity, and
- Public notification actions.

An important point to be remembered is that the items in this category are tied directly to those items under the previous category of advance planning and preparations.

Finally, traffic management activities for emergency recovery consists of two main topics:

- Long-term traffic control and management actions, and
- Right-of-way clean-up concerns.

IMPLEMENTATION STATEMENT

Traffic management requirements for an emergency can vary dramatically from event to event, ranging from the use of standard traffic control procedures and devices during a relatively localized emergency to the implementation of highly innovative and controversial practices that may be necessary for a particularly devastating or widespread emergency. It is hoped that the examples and points made in the synthesis will stimulate discussion and evaluation within an agency as to how it may utilize these or other techniques should the need arise.

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1. INTRODUCTION

As a major hurricane approaches the upper Texas Coast, residents in Galveston and surrounding communities are encouraged to evacuate the area. Interstate 45 between Galveston and Houston quickly fills with vehicles fleeing the region. The trip between Galveston and Houston, which normally takes 45 minutes, lasts several hours as traffic crawls inland.

In Dallas, a semi-tractor trailer carrying hazardous chemicals jackknifes during the evening peak period on the Interstate loop around the city. The freeway is closed for several hours, and a nine-mile traffic queue eventually develops behind the closure.

In west Texas, a small grass fire escalates because of strong winds and dry conditions until it encompasses several square miles and a rural highway route. For several days, traffic on that route must be stopped a number of miles upstream and diverted several miles out of its way around the fire.

A severe weather system dumps several inches of rain over a large area in central Texas. For the next several weeks, hundreds of bridges and sections of roadway are washed away by floodwater moving downstream to the Gulf of Mexico. A number of small towns have all access roads washed away, trapping the residents until emergency road repairs can be made.

These events, seemingly unrelated, have a common thread running between them; they all significantly affect the motoring public. Emergency situations of one type or another occur in all locations. Such situations typically result in traffic delays and congestion, as well as increased risk to persons or property. In order to reduce the potential impact that different types of emergencies have upon transportation, steps must be taken to prepare for transportation emergencies.

Certain types of emergencies, such as freeway incidents (accidents, stalled vehicles, etc.) have received a fair amount of attention in recent years. Basic goals and guidelines for managing traffic at incident locations have been documented in the literature (1-4). Although the majority of incidents are routine, incidents of extremely large or hazardous nature do occur periodically. These often require much more involvement and effort by several federal, state, and local agencies to bring them under control. Figures 1-1a and 1-1b illustrate such an incident.

Significant efforts have also been expended on certain types of non-incident emergencies (such as hurricane evacuation), attempting to predict the magnitude of the traffic problem expected and to suggest potential actions that could be taken to alleviate these traffic problems (2-5). However, attention has not always been given to the coordination within and between public agencies to implement these actions.

Figure 1-1a Major Freeway Accident

Figure 1-1b Major Freeway Accident (Cleanup)

There are many other types of transportation emergencies for which little or no specific guidance exists, those which are extremely unusual and occur so infrequently that detailed planning and analysis efforts are not feasible nor warranted. As examples, Figures 1-2 through 1-4 illustrate a few of the different types of emergencies which have occurred in Texas. In Figure 1-2, a construction crane tipped over across the freeway. In Figure 1-3, a truck ran into a bridge support, knocking down one of the beams onto the roadway. Finally, Figure 1-4 shows a train derailment involving hazardous chemicals which required the partial closure of the roadway bridge spanning the tracks. It is safe to say that one can never develop specific plans for all types of emergencies, since by their very nature they are unexpected events. Nevertheless, when they occur, appropriate public and private agencies must respond quickly and effectively to protect life and property and maintain mobility in the area to the extent possible. General plans should exist for all types of emergencies for which detailed planning is not feasible.

In summary, although existing information on certain types of emergencies can serve as a basic starting point towards emergency traffic management planning, there remains unanswered questions of how to best extend broad traffic management policies and guidelines to specific agreements, lists, and action plans that the highway agency can utilize under emergency conditions. In response to these needs, the Texas Transportation Institute, under sponsorship of the Texas State Department of Highways and Public Transportation and the Federal Highway Administration, has undertaken a study to improve traffic management planning and procedures for major emergencies and evacuations. The primary focus of the first year's efforts were on determining the current state of the practice of emergency traffic management from a state and national perspective. This was accomplished through an extensive review of the literature and through a survey of current emergency traffic management plans and procedures from state and local highway, governmental, and law enforcement officials within Texas and across the country. This information was then synthesized, the results of which are presented in this document.

Definition of Transportation Emergencies

Before beginning an overview of traffic management for emergencies, it is necessary to step back and define what exactly constitutes an "emergency." A number of different definitions have been put forth through the years, such as the one by S.C.Tignor (1):

> "A general definition of a transportation emergency is an extraordinary event that causes congestion, delay, confusion, and/or general disruption of one or more modes of transportation. Such events may include spills, vehicle breakdowns, acts of nature, infrastructure defects, and accidents, among many others.... Transportation emergencies may result in long-term disruption of service, displacement of people from their residences, and loss of life."

Figure 1-2 Freeway Closure Incident

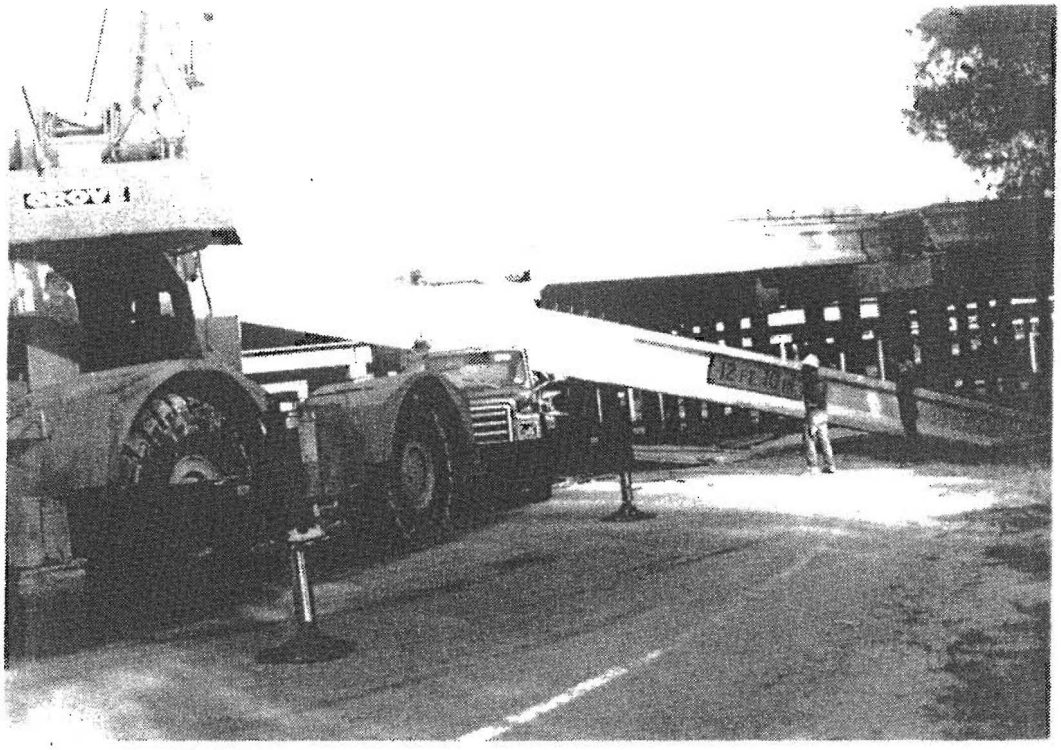

Figure 1-3 Bridge Support Impact Incident

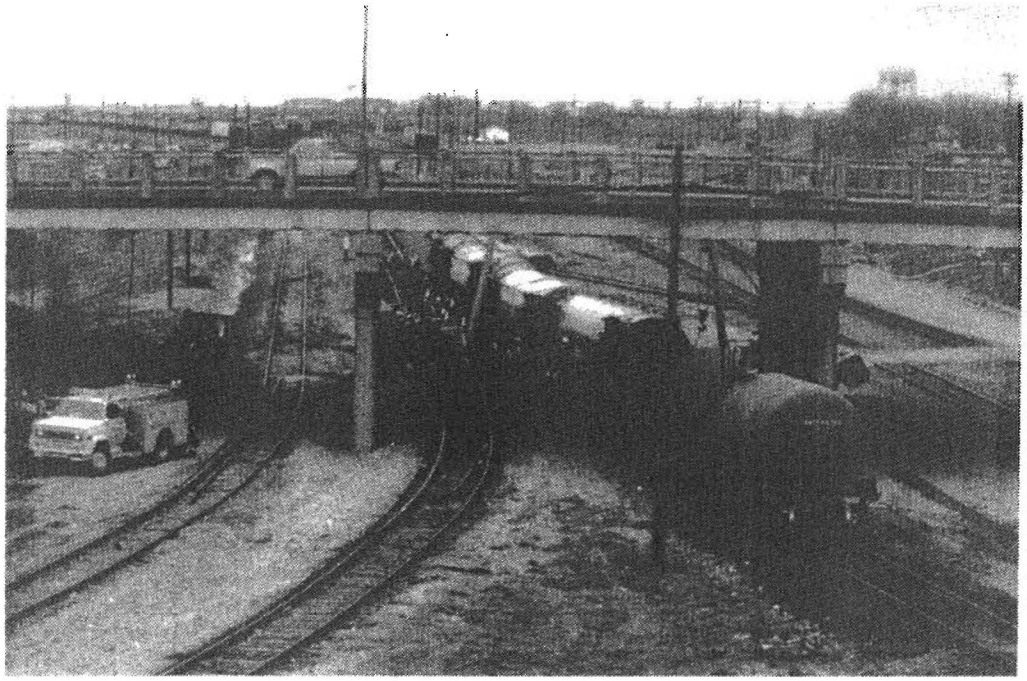

Figure 1-4 Train Derailment with Hazardous Chemicals

However, such a broad definition does not recognize an important facet of a transportation emergency, that being the context within which the "emergency" occurs. In large urban areas, vehicle breakdowns and accidents are such frequent occurrences that specially-designed responses (i.e. incident management systems) have been programmed into the day-to-day management of the transportation system. In this context, very few of these events can truly be called an emergency. On the other hand, an accident on a narrow roadway section in a rural area may block an entire roadway, with no alternative route around the incident existing close by. Because of the nature of the accident, special equipment to free the occupants from the wreckage may need to be brought in from some distance away. Here, the events could be considered an emergency, both from the perspective of the accident response measures and from the traffic wishing to use that roadway.

For purposes of this report (as well as the entire study focus), a transportation emergency is considered to be those events which affect the transportation system in such fashion for which the response measures required or the resulting traffic impacts are not part of the normal day-to-day operations of the transportation system. The response may be unusual in terms of the number and types of agencies involved, in the amount of personnel and equipment resources required, or in the actions required away from the emergency scene (i.e., evacuations, upstream road closures, etc.). Likewise, impacts upon traffic may be unusually severe (such as the complete closure of a freeway), of especially long duration, or require very special reactions by the motorists.

Categories of Transportation Emergencies

Each emergency situation is different, and specific plans and procedures for every type of emergency is neither necessary nor desired. In fact, there are those that advocate a generic emergency response plan, one that is implementable regardless of the emergency situation (2):

> "The all-hazard plan is the simplest to develop, easiest to implement, and most likely to remain current. This approach is founded on the premise that the way an emergency is managed should not depend on the type of emergency.... Response to emergencies will be more efficient if people and procedures are as close as possible to those of normal times..."

Realistically, some differentiation is required because of the diverse requirements that dissimilar types of emergencies place upon the transportation system and the various public agencies affected. In this report, a basic distinction is made between emergencies where agencies take a proactive approach, wisely investing in detailed advance planning and implementation efforts; and those emergencies where agencies must utilize a reactive approach. Examples of emergencies where a proactive approach can be taken include emergency plans for hurricane evacuations, nuclear and chemical plant disasters, and in some instances, flooding. Examples of reactionary emergencies include tornadoes, hazardous material spills, or other events causing major damage to a component of the transportation infrastructure.

It must be emphasized that even though many types of emergencies require a reactionary role be taken by the highway and other public agencies, it is possible to perform emergency management planning for these types of emergencies. However, it does require a change in philosophy of many officials who believe that the idea of emergency planning is a wasted effort. Time and again, those who have had to respond to major emergencies have strongly urged the need for planning (3):

> "Good information, warnings, and contingency planning are essential for effective responses to natural hazards. The idea that nothing can be done to prepare for volcanic disasters or earthquakes or other major hazards is foolish and contrary to the evidence provided by Mount St. Helens... In a disaster situation where quick reactions are necessary, people and agencies tend to rely on what and who they know... Without proper information and warning, the task is more difficult and chances have to be taken which may not always turn out right."

Organization of the Report

This report is devoted to a state-of-the-practice overview of planning and management of transportation emergencies. The report is divided into three more chapters. Chapter 2 addresses the basic legal and legislative issues that influence

emergency planning and response. In Chapter 3, the traffic management practices for major emergencies are presented. Sections are provided on each of the following:

- o Advance planning activities
- o Activities during emergencies
- o Activities during recovery

The final chapter (Chapter 4) presents a summary of the findings from the body of knowledge gathered on this topic and presented in the earlier chapters. To further add to the information contained in the body of the report, case studies of two major national emergencies (the 1989 Loma Prieta earthquake in northern California and the 1989 Hurricane Hugo landfall in Charleston, South Carolina) are offered as appendices.

2. LEGISLATIVE AND LEGAL ISSUES

This chapter provides an overview of the federal and state legislative requirements and guidelines influencing traffic management for major emergencies. In addition, the liability issues that impact transportation emergency planning and management are summarized.

Federal Requirements and Guidelines

Agencies Involved

Federal Highway Administration (FHWA)

The need for, and authorization of, transportation readiness planning for emergencies can be traced to the beginnings of the Cold War and the resulting efforts to prepare for possible nuclear attack. From a transportation perspective, this began with the Civil Defense Act of 1950 which, by Presidential Order, assigned the "Bureau of Public Roads" (which is now FHWA) to an advisory role in these preparations. Then in 1958, FHWA was formally assigned the responsibility of developing a national emergency highway traffic regulation program. Its position in emergency preparations and operations was then reaffirmed in 1969 through Executive Order 11490 (4), which directed the Secretary of Transportation to:

> "...develop a capability to carry out the transportation operating responsibilities assigned to the Department, including but not limited to... Emergency management of all federal, state, city, local, and other highways, roads, streets, bridges, tunnels, and appurtenant structures..."

According to this document, these responsibilities included:

(a) The adaptation, development, construction, reconstruction, and maintenance of the Nation's highway and street systems to meet emergency requirements,

(b) The protection of the traveling public by assisting state and local authorities in informing them of the dangers of travel through hazardous areas, and

(c) The regulation of highway traffic in an emergency through a national program in cooperation with all federal, state, and local governmental units or other agencies concerned.

The Secretary subsequently delegated these and other highway-related emergency responsibilities to FHWA.

Of course, transportation issues are just one part of emergency management planning or response. Emergency transportation planning, management, and repair must

be coordinated through all affected agencies. Some of the more important agencies with involvement in emergency transportation management are also described below.

Federal Emergency Management Agency (FEMA)

FEMA is the agency responsible for discharging the emergency preparedness functions assigned to the various Federal departments and agencies (such as FHWA) and for providing natural disaster preparedness planning assistance to state and local governments. It is the focal point within the federal government for emergency management activities relating to both peace and war (4). The scope of responsibilities of FEMA is broad; its mission is to save lives, reduce suffering and loss of property, and to provide an improved basis for recovery from natural, technological, and war-related emergencies.

From the standpoint of the operation and repair of the transportation system during and after emergencies, the role of FEMA is critical. In the event of an emergency, the President of the United States delegates to FEMA the responsibility of financial disbursements from federal funds to state and local government agencies for repairing and restoring public facilities such as streets and bridges (5).

Office of Emergency Transportation (OET)

The OET, a component of the Department of Transportation, is solely dedicated to emergency preparedness of the transportation system. It is primarily engaged in the development, coordination, and review of policies, plans, and programs for attaining and maintaining a high state of appropriate Secretarial offices, operations administrations, external agencies, and industry. The OET ensures that emergency plans are developed and an acceptable state of readiness is achieved in each transportation operating and support agency (4).

Other Miscellaneous Agencies

An all to common type of transportation emergency affecting multiple agencies are accidents involving hazardous material storage or transportation. The number of agencies affected will depend on the severity of the incident and type of hazardous material. Some of the agencies which may be involved include:

- Department of Energy (DOE)
- Environmental Protection Agency (EPA)
- Nuclear Regulatory Commission (NRC)
- Materials Transportation Bureau (MTB)

Another agency not directly affiliated with the federal government but with important national implications is the Chemical Transportation Emergency Center (CHEMTREC),

operating 24 hours a day, 365 days a year (6). CHEMTREC is an information center which provides immediate technical information and advice for those at the scene of a chemical transportation emergency. In addition, CHEMTREC promptly contacts the shipper of the chemicals involved for more detailed assistance and appropriate follow-up procedures. CHEMTRECs capabilities have been recognized by the Department of Transportation, and a close working relationship has been forged between these two agencies.

Guidelines Established

From a national perspective, the most significant document in emergency transportation planning is the Guide for Emergency Highway Traffic Regulation (4). The guide was developed to assist states in organizing effective emergency transportation plans and local level emergency highway traffic regulation training programs. For many years, the guide focused on post-nuclear attack emergency management of the nation's highway system. However, the guide has been enhanced periodically, such that the concepts now presented in the guide have application to a wide variety of natural and technological emergencies (4). The guide does stress the fact that it does not provide detailed assistance about specific traffic control and management actions. Instead, resource management guidance is provided to assist individual states in developing more specific emergency plans to accommodate each one's unique political, geographic, and traffic characteristics.

In addition to the general guidelines established for emergency highway traffic regulation, the federal government has been very active in providing assistance for planning for and dealing with hazardous material (HM) incidents. The Emergency Planning and Community Right-to-Know Act (7) of 1986 establishes requirements for federal, state, and local governments and industry regarding emergency planning and reporting on hazardous materials use and transportation. The requirements are divided into four main categories:

- Emergency planning
- Emergency release notification
- Community right-to-know reporting requirements
- Toxic chemical release reporting-emissions inventory

Concern over hazardous material release is no longer limited to those areas in the vicinities of chemical plants and storage facilities. In 1981, it was estimated that 4 billion tons of hazardous materials were shipped nationwide in over 413,000 tank trucks (8). Such widespread transportation places a burden of preparation for hazardous material incidents among all governments, from the federal down to the county or city level.

This high level of hazardous material transportation continues to extract a high cost from society. From 1981 to 1985, there were 54 deaths and 473 injuries from on-highway hazard releases, or an average of approximately 11 deaths and 95 injuries per year in the

United States. Approximately 90 percent of the deaths and 25 percent of the injuries were attributed to releases resulting from traffic accidents. Releases resulting from traffic accidents were about 100 times more likely to cause deaths and three times more likely to cause injuries than releases from other causes. (9)

In 1980, FHWA sponsored the development of a risk assessment methodology for selecting hazardous material routes in urban areas (10). The Dallas-Ft. Worth region has recently adopted hazardous material routes which were selected based on this methodology (11). This methodology makes it possible to estimate the trade-offs associated with route alternatives in terms of public exposure in the event of an incident. Unfortunately, the methodology does not take into consideration the capabilities of various local entities to deal with hazardous material incidents. The routing of hazardous material traffic through less populated sections of an urban area (as well as through rural areas and small towns) where emergency response agencies are less equipped to deal with hazardous material incidents continues to be an emotionally charged issue (12,13,11).

State Requirements and Guidelines

As stated in the federal guide (4), each state has the responsibility for developing its own emergency management plan. The Texas Emergency Management Plan (14) was developed by the Emergency Management Council, made up of representatives of various state agencies, boards, commissions, and volunteer groups. The responsibilities and duties of each member agency is spelled out in the plan, which was issued under the authority of the Texas Disaster Act of 1975 (15).

The Texas SDHPT has been given the primary responsibility for providing engineering leadership, coordination, and implementation during emergency situations through the Emergency Management Council. In these situations, the SDHPT is directed to:

- Maintain highway facilities for disaster transportation
- Construct temporary highway facilities when needed
- Provide emergency signing, communications, and other transportation functions along priority and disaster highway routes
- Perform damage assessment inspections of roadways as needed.

However, the Department also serves in several important supporting roles. For example, the Plan directs the SDHPT to assist the Department of Public Safety and local governments with traffic control stations where established, and to provide information on transportation routes for disaster operations. This delegation appears to be consistent with that given to highway agencies in other states. For example, the disaster plan for Arizona (16) designates the Department of Transportation as a support agency for the following responsibilities:

- Communications
- Damage assessment

- Law enforcement
- Fire services
- Rescue
- Emergency work
- Recovery assistance
- Hazardous materials

In Texas, each agency which is a member of the Emergency Management Council is required to prepare and keep current an annex to the Emergency Management Plan. These annexes delineate the general duties and responsibilities of the respective agency and establish procedures for centralized direction and control of the agency resources in response to a disaster or other emergency. The duties for the SDHPT are outlined in Annex M.

Liability Issues

Agency liability has become one of the most important topics in emergency preparation, response, and recovery. Although it has been commonly assumed that agencies and individuals working for that agency are immune from liability in times of emergency, experiences of several agencies indicate that this is not always the case in today s litigation-prone society. For example, one court ruled that agency immunity existed for emergency policy decisions and planning, but that negligence in the implementation of these decisions was not immune (17). Of course, emergency situations often call for special actions and decisions that must be made on the spot, and laws do exist to help protect those acting with the best interests of the public at heart. However, the trends suggest that immunity laws will continue to be challenged in the future (17), and agencies need to react to protect themselves and their personnel.

An overview of past liability problems documented by various highway agencies indicates two areas of concern. These are:

- The use of volunteers
- Emergency training

Volunteers

In most any natural or man-made disaster, the resources of public entities are often stretched to the limit, and the assistance of volunteers is absolutely essential. However, their use places a special burden upon the public agency. A presentation at a recent hurricane planning and response conference (18) identified a number of important questions that an agency needs to consider when making use of volunteers. Responses to these questions were also suggested so as to minimize the risk to which the agency is exposed.

1. *How are volunteers to be selected? Does the agency go looking for them, or do they come to the agency?*

It has been suggested (18) that an agency have a plan for selecting volunteers as well as for how to use them. Such a plan appears important both from the standpoint of administration and supervision as well as reducing the liability exposure borne by an agency.

2. *Are there job standards for the volunteers to meet? Are these different than those of the normal agency employees?*

When volunteers are permitted to perform tasks that are normally performed by a regular agency employee, the volunteer should meet the same qualifications that the employee had to meet to perform that job. For example, if an employee must have a motor vehicle check, a physical exam, and have taken a defensive driving course to operate a vehicle owned by the agency, then a volunteer should have the same qualifications to also operate a vehicle.

3. *How are volunteers to be supervised and evaluated?*

Agencies are strongly encouraged to develop a plan for supervising and evaluating volunteers (18). Decisions regarding who, how, and what needs to be supervised should be made ahead of time.

Another important topic discussed at the conference was that of the agency's liability for injuries to, or caused by, volunteers. It was suggested that volunteers be covered under worker compensation programs or employee major medical coverage as seen fit by the agency in order to minimize problems caused by volunteer injuries. Injuries to third-parties caused by volunteers are another type of liability problem that an agency must address. The strongest defense suggested is for the agency to have as much knowledge about existing immunity laws as possible. It may be that volunteers are included in such laws. It was also recommended that the agency decide ahead of time on its policy regarding these issues and to state them before the volunteers begin their efforts.

Emergency Training

The training of employees (and possibly volunteers) to perform in emergency response and recovery operations has surfaced as another source of liability concern. Training has always been viewed as important in obtaining the most from personnel, helping to alleviate problems in emergency plans before they are needed, and to make emergency activities more efficient. However, there now appears to be added incentive for training, that being to avoid possible litigation in the event of injuries or property damage caused by emergency personnel. The liability an agency bears for failing to properly train its personnel under normal situations (i.e., a police officer not properly trained in firearms usage who accidently injures someone) is gradually being extended

into more dynamic, emergency scenarios (17). In the future, if it can be proved that adequate training could have prevented damages that occur, it is likely that the agency will start being made liable for failing to provide that training (17).

3. TRAFFIC MANAGEMENT ELEMENTS FOR MAJOR EMERGENCIES

This chapter provides a summary of traffic management practices for major emergencies. This summary is based on information collected through an extensive literature review, a written survey of selected state and local officials charged with traffic management responsibilities during major emergencies, and direct communications with these and other traffic management and emergency management officials within Texas and across the nation. Documented traffic management experiences from a number of past major natural and man-made emergencies provide an excellent barometer of the benefits of specific courses of actions taken, as well as to illustrate some of the consequences of improper actions or of inaction. These experiences are integrated throughout the chapter to provide a point of reference for the various traffic management components that have been identified as important in planning for and successfully enduring major emergencies.

Three major phases have been identified with respect to the traffic and transportation needs of major emergencies. These are:

1. Advance Traffic Management Planning and Preparation
2. Traffic Management Activities During Emergencies
3. Traffic Management Activities For Emergency Recovery

The remainder of the chapter focuses on each of these phases.

Advance Traffic Management Planning and Preparation

If anything has been learned from the myriad of emergencies that have occurred in recent years (both at a state and a national level), it is that advance traffic management planning is of paramount importance to a region's ability to successfully weather a major emergency. Traditionally, only the more predictable types of emergencies (i.e., hurricanes, nuclear plant disasters, icy roads) have received a planning emphasis. These planning activities have typically resulted in formalized plans or standards of procedures spelling out specific agency assigned tasks, number and location of traffic control devices, etc. Planning at this level of detail is obviously impractical for the majority of emergencies that do occur, those which are unpredictable in nature. However, experiences indicate that a number of preparations that are emergency-generic can be made to facilitate proper agency reactions when an emergency of some type does occur.

To date, advance planning and preparation efforts have fallen into the following categories:

- Coordination Agreements Between and Within Agencies
- Personnel and Equipment Resource Assessment
- Transportation Network and Traffic Control Evaluation
- Communication Systems Development
- Training

Coordination Agreements Between and Within Agencies

Most major transportation emergencies affect more than one agency. In some instances, more than one division within a single agency may be involved. Cooperation and coordination between the affected agencies, both in preparing for and reacting to actual emergencies, must exist if the emergency situation is to be resolved in an efficient and timely manner (1).

In general, coordination and cooperation between and within agencies has been accomplished through either formal or informal agreements. Formal agreements exist in writing, and officials from each member agency sign the agreement thereby agreeing to its contents and actions spelled out (14, 17). In contrast, informal agreements sometimes exist, either verbally or in some written form (such as a letter or a memorandum). However, these agreements do not necessarily have official authorization of upper agency management. Regardless of type, these agreements include such items as (19, 20, 21, 22):

- Identification of lines of authority or chain of command during an emergency
- Names and addresses of key personnel from each agency
- Each agency's response and equipment capabilities
- Authority to request aid from other agencies
- Mutual-aid agreements
- Method and sequence of alerting each agency of an emergency
- Procedures for incorporating and coordinating assistance from additional agencies if the emergency warrants

Based on the information obtained, it appears that formal agreements between agencies have been used predominantly for predictable events that receive some preplanning emphasis (icy roads, hurricanes, nuclear power plant and chemical plant disasters, etc.) (23, 24, 25). These formal agreements commonly exist as part of detailed emergency response plans which also designate specific agency tasks. In contrast, informal agreements appear to be more useful as a means for coordination, cooperation, and assistance between agencies independent of the type of emergency being addressed. In general, informal agreements have been used to indicate consensus as to who the lead agency (or official of that agency) will be during an emergency situation, and has in some cases verified each agency's commitment to assist if requested.

Experiences at several emergencies nationwide illustrate the problems that exist if some lines of communication between agencies are not in place before an emergency occurs. The volcanic eruption at Mount Saint Helens in 1980 is just such an example. The federal and state support efforts were operated out of separate offices, and a certain feeling of animosity existed between the offices. Communications between offices and local citizens were hampered by extremely overcrowded telephone lines. Overall, the response operation was in a state of confusion for the first few days after the eruption until some operating agreements between federal, state, and local agencies were ironed out (3).

Personnel and Equipment Resource Assessment

It has been stated that resource identification and allocation are the nuts and bolts of emergency planning (2). One of the biggest problems of both the 1989 California Earthquake and Hurricane Hugo in South Carolina was the lack of proper equipment to deal with the emergencies (26, 27). Given the quick responses required in many emergency situations, the preparation and maintenance of current resource lists by each agency can save precious time as well as facilitate more efficient response efforts.

The resources that can be provided by transportation and public works agencies during and after emergencies can be quite significant. These agencies typically possess large amounts of materials, heavy equipment, and personnel with engineering expertise, items which are often in high demand in an emergency. However, those responding to emergencies must be able to know what equipment and materials are available, where they are located, and who to contact to obtain them. The Guide for Emergency Highway Transportation Regulation (4) suggests that appropriate agencies develop a jurisdictional map and a listing of storage locations with the materials and equipment at each, a listing of mobile radios and call numbers by area, and the locations of stockpiles of barricades and signs.

Experiences at Hurricane Hugo suggest that resource lists for each agency should be integrated as part of planning efforts to develop a region-wide resource assessment for use by all agencies during emergency situations (28). It was stated that this regional listing should also be updated throughout the emergency to provide a realistic assessment of resources in real time. In the case of Hurricane Hugo, it was found that the barrage of donated equipment, although much appreciated by the local agencies, could not be utilized effectively because there was no way of knowing what had been received (29).

Finally, it appears that the private sector role during major emergencies can be particularly significant and should not be overlooked when assessing the resources of an area. A particularly devastating emergency will likely require resources in excess of even those pooled together by all agencies. Annex M of the Texas Emergency Management Plan makes reference to the American General Contractors (AGC) Booklet "Plan Bulldozer," which provides a list of available large equipment. The Annex recommends that local private organizations be utilized in obtaining needed resources and equipment from the contractor community in time of a disaster (30). The need for private sector participation can also extend beyond these large scale resources, however. During the California earthquake, for example, rescue and clean-up workers reported a severe shortage of chain saws and portable lighting (26). During the same emergency, police and public works agencies reported that traffic control requirements at major intersections placed the biggest strain on their resources. If the city would have had access to a large number of portable generators and a plan for their deployment to these intersections, police and public works resources could have been utilized much more effectively (26).

Transportation Network and Traffic Control Evaluation

Another important aspect of advance traffic management planning and preparations of many agencies has been the evaluation of the transportation network and of the major traffic control requirements that will exist before, during, and after an emergency occurs. Again, the most detailed assessments have typically been made in conjunction with extensive planning efforts for predictable emergencies (hurricanes, nuclear plant disasters, hazardous material truck routing). However, the concept applies at a more general level to any emergency traffic management planning efforts.

Transportation network and traffic control evaluation is an integral component when considering the following emergency traffic management planning topics:

- o Evacuation and Emergency Access Routes
- o Detour/Diversion Routes
- o Hazardous Material Routes and Response

Evacuation and Emergency Access Routes

As stated previously, most of the planning efforts for evacuation and emergency access routes has been performed in the context of hurricanes or nuclear/chemical plant disasters. State highway organizations should establish and maintain a close liaison with the State Emergency Services in order to insure that State Emergency Highway Transportation Regulations are compatible with other State emergency planning efforts (4) The transportation network plays a vital role in the overall planning efforts for evacuations, for the characteristics of the network defines the time that it takes to evacuate an area. This information is then integrated with characteristics of the emergency (intensity, duration, and breadth of geographical coverage) to determine when decisions must be made in order to complete the evacuation before the emergency will impact the evacuation area. Computerized models to assist in this assessment have been developed for hurricanes (for example, the ESTED-TX (20, 31) and HURREVAC (32) models) and for nuclear plant disasters (i.e I-DYNEV (33).

Local agency knowledge of the characteristics of the network is critical to the proper application of these models as well as in implementing action plans to manage traffic on these routes more effectively. For example, it has been stated that roadways that will be inundated by heavy rains should be omitted from an evacuation road network plan (33). Evacuations of hospital patients, nursing home residents, and correctional facilities are other considerations that have been identified during previous planning efforts (19). Special traffic control measures that improve operations have also been instituted by various agencies. For example, residents in coastal evacuation zones in Duval County, Florida are assigned to the nearest east-west arterials south of each zone so that the predominant movements for evacuations are right-turns onto the major escape routes, thereby minimizing the impacts of entering traffic onto these routes (34).

Transportation network and traffic control evaluation is not restricted to planning efforts for predictable emergencies, however. Although routes requiring emergency highway traffic regulation cannot be determined until an emergency occurs, the use of routes in the region can be analyzed and planned in advance. Routes which have a high probability and feasibility for emergency use can be identified by considering their location; survivability; ease of restoration; and functional, service, and strategic characteristics. Potential bottlenecks, barriers, and other problems can be analyzed in advance (4). An excellent example of the application of this concept is the system of roads in Kentucky identified for emergency transportation use in the event of an earthquake. The roadway system selected consists mainly of older two-lane highways instead of parkways or other limited-access roads, because the older highways had fewer bridges and overpasses that could be damaged in the event of an earthquake (35).

The continued advancements in computer technology will undoubtedly lead to improved abilities to plan and respond to transportation emergencies. Advancements in technologies such as Geographic Information Systems (GIS) databases with minimum path routing capabilities (36, 37) will provide agencies with the ability to quickly evaluate and select evacuation routes, and to access specific information about these routes in real time (38). The city of Troy, MI is one of the first cities to develop and utilize a municipal information management network. The system includes the capability to calculate and recommend routes that emergency vehicles should take to an incident location based on distances, speed limits, height or load restrictions, road construction, other obstructions, and traffic congestion. Shift changes and other peak period information would be included in the database and will be automatically factored into the route recommendations (39). These claims have not yet been verified through real-world applications, however.

Detour/Diversion Routes

Transportation network and traffic control evaluation is also an important part of the effort to plan for detour/diversion routings around major roadway incidents. Usually, law enforcement has the primary responsibility for determining when this is necessary, but the transportation agency provides a support role in providing necessary personnel and equipment (stop signs, detour signs, arrow signs, road closed signs, channelizing devices, barricades, battery-operated flashers, etc.) to enact these detours (40).

The extensive alternative route plans the California Department of Transportation (CALTRANS) has developed for the Los Angeles freeway system is an excellent example of advance traffic management planning of detour/diversion routes for major transportation emergencies. Alternative route maps have been developed for over 3500 freeway locations. All existing streets that might serve as alternative routes were identified and inventoried for every section of freeway in the Los Angeles area. The best possible route(s) for each potential incident location was then identified. City transportation and enforcement agencies played a key role in this identification, providing specific local details as to the location of churches, schools, hospitals, and sensitive neighborhoods.

These selected routes were transferred onto a local map of the area, along with the equipment and manpower efforts required to implement the alternative route plan (41).

Hazardous Material Routes and Response

Planning for effective community response to nuclear power reactor or other hazardous material emergencies is a joint effort by nuclear facility management and local, state, and federal agencies. State highway emergency planners are encouraged to establish a working liaison with State Emergency Services/Civil Defense Agency Population Protection Planners. (32).

The increased transport of hazardous materials has required an increased emphasis upon advance traffic management planning for hazardous material routing and incidents. Methodologies have been established for assessing the risk of various routings through an urban area (10) in order to select those with the lowest risk potential, and specially-designed response procedures to hazardous material incidents have also been established.

Communications Systems Development

Because of the dynamic nature of emergencies, clear and reliable means of communication within and between agencies are essential. The lack of good communication abilities appears to be one of the most critical problems facing transportation agencies. With respect to communications within a given agency, it has been suggested that planners often rely too heavily on a single mode of communication, such as mobile radio or telephone, and ignore the need for a reliable back-up system (2). As the organizational structure of an agency changes, its emergency communications procedures must also change accordingly. One suggestion made has been to appoint a communications specialist who performs ongoing system checks and makes appropriate recommendations for change (2).

Communications between agencies presents additional concerns during emergency situations. Communications between state highway and law enforcement agencies has been cited as particularly critical during times of emergency (4), as has the communications between contiguous state highway agencies (4) since the impacts of emergency situations do not necessarily follow state boundaries. One method available to public agencies during emergencies is the Amateur Radio Emergency Service (ARES). ARES is a volunteer radio communications service available to federal, state, county, and city government agencies as well as to non-profit organizations. More than 25,000 amateurs have voluntarily registered their services to provide reliable primary or secondary communications links for governmental agencies when needed. Many communication modes are possible through this service, increasing its flexibility and abilities to continue communications regardless of the emergency situation presented (42).

Amateur radio operators assisted with communications during the Mexico City earthquake of 1985, during brush fires in California and tornadoes in the midwest, and during hurricanes on the east coast (42). Amateurs were particularly vital to the communications capabilities for government and nongovernment relief agencies after Hurricane Hugo (43).

A final communications link that has been shown to be essential during emergencies is between government agencies and the public media. Obviously, coordinated communications between the various agencies involved in an emergency and the media is essential; conflicting instructions from multiple sources can be quite detrimental (1). Not only does proper communications with the media facilitate proper public response, it can help control the impact of the media's presence at an emergency. For example, during a hazardous materials incident in California in which a truck was leaking a toxic orange cloud of corrosive acids, a media helicopter ignored FAA restrictions of airspace above the incident and flew into the cloud. The downdrafts blew the gas into the command post area and into on-site response personnel. The helicopter crew was also overcome by the fumes and had to make an emergency landing on the freeway, further adding to the incident (25). Apparently, the media agency was not satisfied with the information it was receiving along official channels, and decided to get information on its own.

Public media does play an ever-increasing role in obtaining proper public response to emergency situations. This has been recognized for some time in such large cities as Chicago, where the Illinois DOT provides real-time traffic information from its surveillance and control center to local media stations for dissemination to the public (44). This aids motorists in avoiding incident locations, and reduces the magnitudes of the impacts of the incidents themselves.

The Public Information Emergency System (PIES) is a radio communications network that is now operational and is being expanded in the Houston/Galveston area. PIES is the first such disaster network in the nation, and has so impressed the Federal Communications Commission that it could become a model for other cities nationwide and along the Gulf coast (45). The system utilizes a special radio frequency to link all of the participating Emergency Operations Centers in the 41 suburban cities in the area with more than 60 media outlets in the metropolitan area. The system proved particularly crucial when Hurricane Alicia hit the upper Texas coast in 1980. Baytown's local radio station lost its broadcasting capabilities on the day that the hurricane made landfall. A Houston radio station picked up the information from the Baytown Emergency Management and Preparedness coordinator, and relayed it back to the Baytown residents (45).

Training

The final aspect of advance traffic management planning and preparation is that of training, both of agency personnel and of volunteers who come to assist in times of particularly devastating emergencies. It has been stated that training is one of the key

elements of any emergency response. Proper training will bring everyone together, and provide a smooth management scene (25). Unfortunately, proper training, particularly for initial-response personnel, can be extremely difficult to implement (46).

Mock disaster exercises are one method of providing effective training for emergency response. Detailed post-mortem sessions with personnel enable the refinement of response plans, identify weak links in personnel or equipment, and aid in resolving problems caused by staff turnover (1, 2). The topic of such exercises can vary, depending upon the focus of the agency at a given period in time. For example, mock hurricane exercises, involving the coastal emergency management centers, are held every spring before the hurricane season begins (47). Hazardous material incidents are another potential disaster exercise scenario.

The recent disasters in South Carolina and California brought to light particularly critical issues with respect to volunteers assisting in disaster relief, and more importantly, in their training. One source stated that while 13 people died during Hurricane Hugo in South Carolina, 26 people (mostly untrained volunteers) died during recovery operations (48).

Traffic Management Activities During Emergencies

The next traffic management phase of an emergency are the activities that occur during the emergency itself. The number, type, and magnitude of these management efforts will vary dramatically depending on the duration of the particular emergency being addressed as well as on-site specific features (including roadway, traffic, environmental, and political considerations). The following sections describe some of the different traffic regulation and management actions that have been used at past emergencies. These actions are divided into several categories:

- Traffic Control Devices and Signing
- Active Traffic Control and Management
- Emergency Efforts to Increase Roadway Capacity
- Public Notification Actions

It is important to realize that the items discussed in this section are tied directly to the previous section on advance traffic management preparations. Prior evaluations of traffic management and control capabilities (in terms of agreements needed, resource assessments, traffic network evaluation, etc.) by a transportation agency allows that agency to respond quickly and effectively during an emergency situation.

Traffic Control Devices and Signing

Emergency situations present unusual circumstances to drivers. Consequently, traffic control devices and signing are an especially important component of traffic management during emergencies. These devices can include the standard warning and

advisory signs (to warn of such things as roadway or bridge failures, flooding, etc.) and a number of special signs for use by highway agencies for guiding and directing traffic when an area is under an official state of emergency. Several signs in this latter category are worth mentioning, as many highway officials may not be readily familiar with their design or application.

Evacuation Route Markers -- are 18-inch diameter circular signs carrying a directional arrow and displaying the legend EVACUATION ROUTE (49). An illustration of this sign is shown in Figure 3-1. These signs shall be used in advance of and at any turn in an approved evacuation route, and can be used elsewhere for straight-ahead confirmation of the route where needed. Placement of these signs should be made under the supervision of highway officials normally having responsibility for traffic signs, but in coordination with Civil Defense authorities (now called the Office of Emergency Management), and agreement between contiguous political entities to assure continuity of the routes (49). These signs are not used extensively, either in Texas or nationwide (only Florida and Mississippi appear to utilize them). However, one recommendation after the effects of Hurricane Hugo were assessed was that these signs should be implemented more extensively in South Carolina to assist in future emergency preparations (33).

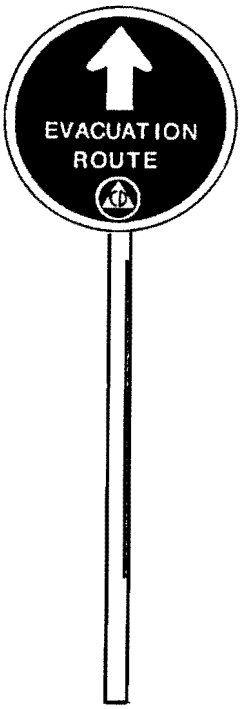

Figure 3-1 Evacuation Route Marker

Traffic Regulation Post Sign -- is used to designate a point where an official post has been set up to impose such controls as are necessary to limit congestion, expedite emergency traffic flow, exclude unauthorized vehicles, or protect the public. A standard STOP sign is used for this mandatory stop, with a supplemental panel (black legend on a reflectorized white background) stating TRAFFIC REGULATION POST (49).

Road-Use Permit Required for Thru Traffic Sign -- is used on an intersection approach to a roadway where a traffic regulation post has been established. The intent of this sign is to notify drivers of the presence of the post so that those who do not have road-use permits issued by the designated authorities can detour onto another route and avoid adding to the screening load at the post. The sign shall be erected in a manner to that of the emergency speed sign. The sign has black letters and a black bonder on a reflectorized white background (4).

Emergency Aid Centers Sign -- is used to guide the public to emergency aid centers established by state and local authorities for civilian relief, communications, and medical purposes. It consists of one of the following legends, as appropriate, or other designating similar emergency facilities (49):

DECONTAMINATION CENTER
REGISTRATION CENTER
WELFARE CENTER
MEDICAL CENTER

Area Closed Sign -- is used to close a roadway that enters an area from which all traffic is excluded because of dangerous radiological or biological contamination. It shall be placed on the shoulder on the right edge of the roadway. Its height should not exceed four feet from the pavement to the bottom of the sign. Unless adequate advance warning signs are used, it should not be placed as to create a complete and unavoidable blockade. If possible, the sign should be located at an intersection that provided a detour route. As shown in Figure 3-2, it should have black letters and border on a reflectorized white background (4).

Fallout Shelter Directional Sign -- is used to direct the public to selected fallout shelters that have been licensed and marked for emergency use. The signs may be erected on all roadways except the Interstate system, when their need has been established by an approved community shelter planning study. The sign is a horizontal rectangle, 30 by 24 inches, containing the identifying "public fallout shelter" emblem in the upper left part of the sign. The colors of the emblem are yellow triangle inscribed in a black circle placed on a yellow square. The words "FALLOUT SHELTER"--the directional arrow, the distance to shelter (which can be omitted when appropriate), and the border are all in black against a white background (49). (See Figure 3-3).

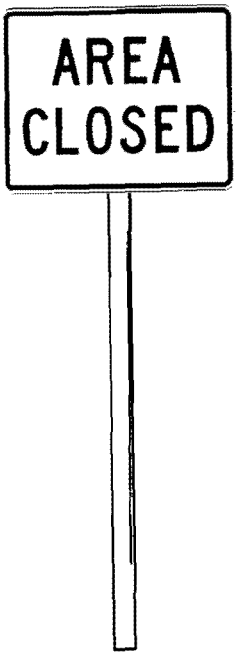

Figure 3-2 Area Closed Sign

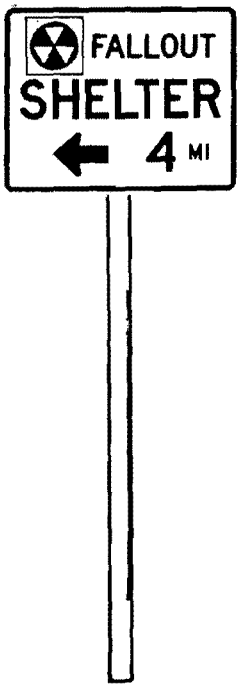

Figure 3-3 Fallout Shelter - Directional Sign

Emergency Speed Sign -- is used on highways where radiological contamination is present to limit the permissible exposure time for occupants of vehicles passing through the area. Since speed zoning would be impractical under such emergency conditions, no numerical speed limit can be prescribed by the sign. Where traffic is supervised by a traffic regulation post, official instructions will usually be given verbally, and this sign will serve as an occasional reminder of the urgent need for a reasonable speed. The sign should be place at random intervals as needed, in the same manner as other standard speed signs. In rural areas, it shall be mounted on the right hand side of the road with its lower edge not less than five feet above the crown of the roadway, six to ten feet from the roadway. In urban areas, the height shall be not less than seven feet, and the nearest edge of the sign shall be not less than one foot back from the face of the curb. Where an existing Speed Limit sign is in a suitable location, the Top Safe Speed sign may conveniently be mounted directly over the face of the older sign, which it supersedes. As shown in Figure 3-4, it should have black letters and border on a reflectorized white background (4).

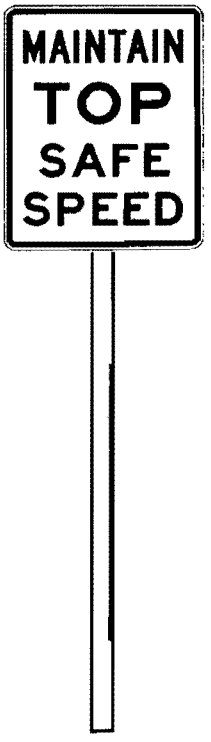

Figure 3-4 Emergency Speed Sign

Other non-standard signs have been used during emergencies. In the 1985 Mexico earthquake, approximately 70 percent of the city's central transportation was wiped out. What were once normal roadway sections became cul-de-saces due to collapsed structures, debris, etc. Major congestion formed in the city center, interfering with search and rescue operations. The lack of sufficient number of traffic signs needed to carry out an operation of such magnitude was an obstacle in implementing a quick traffic diversion and detour strategy. Special traffic signs were needed to warn vehicular and pedestrian traffic of the extraordinary conditions that prevailed, such as near-collapsed structures or demolition and rescue work in progress. For example, two-way signs were posted on many one-way streets, framed in a red circle on a navy blue background. The sign showed two arrows, a white arrow for the original direction of the street and an opposing red arrow to warn drivers of the existence of on-coming traffic. Signs were also installed to prohibit drivers from entering a roadway section where demolition activities were in progress, and signs to warn pedestrians of demolition activities were also installed (50).

Channelizing devices (cones, tubes, barrels) and barricades are other items that are included in this category. These items are essential for such things as closing a roadway and nearby entrance ramps (due to a hazardous material spill or extensive flooding, for example), splitting an exit ramp into two narrow lanes to increase capacity (51), delineating the boundaries of an on-site command post, etc. Also, stop signs are sometimes used to replace traffic signals that have loss power.

During the 1989 earthquake, the City of Campbell, CA mounted or leaned many signs against anything that remained standing, including the back of a pickup truck. Paper reflectorized signs and delineators were found to be lighter and easier to use than flashers on barricades. Officials also mounted STOP signs on two or three barricades across multi-lane arterials so that they could be better seen by motorists (40).

Active Traffic Control and Management Efforts During Emergencies

The second category of actions possible during emergency conditions are those involving law enforcement or other personnel to control and manage traffic in real time. Active traffic control by police officers is often necessary near emergency scenes to facilitate the movement of traffic at intersections or other points where flows conflict. Another important role of enforcement is the restriction, where required, of vehicle access to the emergency area. Depending on circumstances, flaggers may also be used to assist in traffic control during emergencies (25). Also included in this category of actions is the use of real-time information displays such as changeable message signs or highway advisory radio (especially useful during major roadway incidents when traffic must be diverted) (52). Active traffic control is extremely resource intensive, and should only be used where absolutely necessary.

In many instances, these and other active traffic control and management are coordinated through the establishment of on-site emergency command post (25). At this post, all emergency activities (traffic control, resident evacuation, on-site rescue

operations, restriction of access to the emergency area, etc.) can then be better coordinated (25). Typically, this post will be under the command of the local emergency management coordinator or law enforcement commander, with highway agency personnel serving a supporting role (25).

Emergency Efforts to Increase Roadway Capacity and Utilization

The third category of actions are those activities implemented to increase roadway capacity and better utilize existing roadways during emergency conditions so as to accommodate large traffic volumes which have been diverted from their primary route, or to reduce the time required to evacuate a given area. A wide variety of actions are possible, dependent heavily on the specific characteristics of the area and attributes of the particular emergency. The following list provides an indication of the range of actions that have been used or proposed during emergency conditions (34, 53).

- o Use of high-occupancy vehicles and HOV facilities to increase evacuation
- o Conversion of two-way and/or freeway facilities to one-way flow away from the emergency
- o Stationing tow-trucks along major routes to reduce capacity reductions caused by accidents and stalled vehicles and to promote continued roadway flow
- o Suspension of tolls on bridges and toll facilities serving as evacuation or detour routes
- o Prohibiting unauthorized movement of oversize/overweight cargoes within the emergency area

A number of serious implementation issues exist regarding the conversion of roadway facilities, particularly freeway facilities, to one-way flow. In some areas, feasibility studies have indicated that this action would not serve the intended purpose, due to bottleneck restrictions on either end of the roadway facility (54). In other cases, this technique may prove useful. When using this method however, it would be necessary to establish a special usage lane in the opposite direction for emergency vehicles. Although this technique has never actually been applied, it has been contemplated for two past hurricane evacuations (Corpus Christi, South Carolina) (55, 56). Obviously, site-specific characteristics would determine whether or not this action would be feasible at a location. In addition, this type of action would likely require extensive advance planning, suggesting that it would be most applicable to predictable types of emergencies such as hurricanes, power plant disasters, etc.

Public Notification Actions

The final category of actions in this phase is the notification of the public about an emergency and about necessary motorist/resident responses to that emergency. The introduction of the PIES for radio communications (45) (see the section on advance traffic

management planning) is one example of activities in this category. The use of real-time motorist information displays, discussed previously, can also be considered a public notification action. With respect to the management and control of the transportation system during an emergency, the public must be notified as to the emergency traffic controls that have been enacted as well as the location and regulation of emergency routes.

Public media provide the most comprehensive means of notification. Unfortunately, it has been stated that most emergency management plans prepare for everything but how to deal with, and utilize, the press (57). Fortunately, efforts are being made by several agencies to improve actions in this area. For example, the Dallas District of the Texas SDHPT has developed a Severe Weather Communications Plan to improve the dissemination of information about road conditions in the area from agency maintenance personnel to public affairs officers and from them to the media and the general public. These efforts arose out of a recent bout of severe flooding in the area in which over 2,700 calls per day were received in the District office (and an additional 2,246 calls taken at the agency's Travel and Information Division in Austin, TX) requesting information about road conditions (58).

Traffic Management Issues For Emergency Recovery

The final phase of traffic management actions possible are those taken in the recovery phase of an emergency. The extent of emergency recovery depends heavily on the severity of the emergency; localized emergencies, such as a hazardous material spill or explosion, may require little (if any) recovery once the emergency has been eliminated. Conversely, regional emergencies (i.e., flooding, hurricane, earthquake, etc.) will typically require an extensive period after the emergency itself for conditions (traffic and otherwise) to return to normal.

Past traffic management issues during emergency recovery can be grouped into the following general categories:

- Traffic control and management actions
- Right-of-way clean-up concerns

Traffic Control and Management

Traffic control and management can pose special problems during emergency recovery operations. Existing traffic controls may be missing, damaged, or inoperable; roadway segments may be blocked with debris or structurally damaged, requiring extensive detouring; and traffic demands can be significantly different than normal due to residents returning to their homes (in the case of emergencies requiring evacuations). In addition, special signing may be needed to warn vehicular and pedestrian traffic of structures near collapse, or of rescue and repair work ongoing in the area (50).

Most of the traffic control items discussed in the previous section on actions during emergencies are relevant in emergency recovery phases as well (59, 26, 50). A common problem at past emergencies has been the shortage of normal traffic control devices. Lightweight temporary signs made out of fabric or paper have been used successfully on occasion to ease traffic control needs in major emergency recovery operations (40). Resource lists (as discussed under the advance transportation planning phase) are particularly important and can greatly facilitate the procurement and implementation of needed traffic control.

A major traffic control component during emergency recovery operations are police officers, public works personnel, and even volunteers who provide active traffic control at critical intersections. In the recovery phase of an emergency, a top priority of transportation and public works agencies is to get power and repairs made to traffic signals and street lighting at these major intersection so as to free up police and other personnel from this hazardous duty and allow them to focus their attentions elsewhere (40). Other priorities are to make the roads safe again for vehicular and pedestrian traffic, and to provide for the free movement of emergency and utility service vehicles (40).

Right-of-Way Clean Up and Repairs

Right-of-way clean up and repair is one of the last, but certainly not least, components of emergency recovery operations from a transportation agency perspective. Depending on the magnitude of the damages, this activity can take months and be the most expensive part of an agency's entire emergency response effort.

Officials involved in past emergencies nationwide have identified a number of significant issues that have arisen regarding debris cleanup. These are enumerated below for informational purposes:

1. Several agencies reported severe tire shortages during emergency cleanup and repair activities, as downed power lines and sharp objects in the roadway ruined tires almost as fast as they were changed. As part of the cleanup for Hurricane Hugo, arrangements had to be made to obtain tires from out-of-state businesses (60).

2. There were some problems in keeping private property owners from pushing debris from their land into the roadway, rather than removing it from the area themselves. This overburdened the crews attempting to clear the roadways, increasing the time and effort needed to get roadways open and functioning (60).

3. Coordination between transportation and public works agencies and the military, when involved, has been a point of difficulty at some past emergencies. In some instances, military personnel found it difficult to distinguish between the cleanup crews and the looters. In other cases, cleanup actions by the military were not coordinated with those of other agencies, and debris within the right-of-way was moved around a number of times before it was finally removed (60).

4. A lack of knowledge about federal requirements for assistance (regarding bidding procedures, identification of roadway segments to be included, etc.) delayed the beginning of some cleanup activities (60).

4. SUMMARY

This report has presented a synthesis of traffic management issues and procedures for major emergencies. The intent of the report has been to provide the reader with an overview of the various practical concerns surrounding emergency traffic management planning, and to illustrate how necessary planning efforts are for an agency to be truly prepared to respond to any type of emergency.

The need for some type of emergency readiness planning has been mandated through both federal and state laws. Efforts at both the national and state level have led to the development of several documents outlining how emergency transportation planning and management is to be accomplished, and to define (in general terms) the roles and responsibilities of the state transportation agency. However, it is clear that additional preparations are needed. Experiences at past emergencies nationwide suggest that state highway (as well as other) agencies must begin to consider the implications of their planning (or lack thereof) efforts, as the umbrella protection of past immunity laws continues to be challenged. Particularly sensitive areas to a public agency are the use of volunteers and the initiation/improvement of emergency preparedness training programs.

It has been shown that the highway agency can indeed take actions to be prepared for major emergencies, even those that are unpredictable in nature and for which specific plans cannot be developed. Again, experiences at past emergencies nationwide point to the importance of:

- existing interagency and intraagency agreements,
- current personnel and equipment resource lists within the agency and in the possession of those responsible for emergencies of a more regional nature,
- current estimates of the potential problems and/or strengths of the transportation network during times of emergency response and recovery, and
- a strong communications system within the agency, among other agencies, and with the public.

A number of important considerations and examples concerning the implementation of traffic management strategies and devices during emergency response and recovery were presented in this report. The traffic management and control requirements during an emergency can vary dramatically, from the use of standard procedures and devices to highly innovative and controversial practices required during a particularly devastating or widespread emergency. It is hoped that these examples help to stimulate discussion and evaluation within an agency as to how it might utilize these or other techniques should the need arise. With such advance contemplation, it is possible that an agency might be able to utilize them in future emergency situations.

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Appendix A: The 1989 Prieta Loma Earthquake

At 5:04 PM on the warm, sunny afternoon of October 17, 1989, the San Francisco Bay Area experienced a major earthquake. The Loma Prieta Earthquake, named after the peak and ridge near its epicenter, lasted for 15 seconds and registered 7.1 on the Richter Scale. An earthquake of this magnitude can be compared to the energy of a half-megaton nuclear bomb or 500,000 tons of TNT (40). In addition to being accountable for the loss of 62 lives, the quake was also responsible for extensive loss of electric power; ruptured water and gas lines; fires; and earthslides (61). However, the most immediate and serious results were collapsed buildings and the damage to the state highway system. In the 15 brief seconds of the quake, the transportation system in the San Francisco region lost the use of (62):

- the Embarcadero Viaduct, Central Freeway, and I-280 in San Francisco;
- the Bay Bridge, which is the main connection between the East Bay and San Francisco;
- the I-880 Cypress Structure in Oakland; and
- State Highway 17, which connects the Santa Cruz area to the South Bay's Silicon Valley.

Description of Damages

In San Francisco, no structures on the freeway system completely failed. However, severe damage to columns on various structures required closure of three major routes. One of these routes, the Embarcadero Viaduct (I-480), is the major traffic distributor and connector between the San Francisco Bay Bridge and central San Francisco, Chinatown, and the Fisherman's Wharf areas. The Embarcadero Viaduct, Central Freeway (Highway 101), and I-280 will not be completely opened until the spring of 1991. Now debate rages about the safety of all double-decker highways. The state has agreed to follow the wishes of the city on any reconstruction. The future of the Embarcadero Viaduct is uncertain at this time (61).

One segment of the upper roadway on the Bay Bridge collapsed onto the lower roadway. The Bay Bridge under normal operating conditions carries 243,000 vehicles per day. After the quake, individuals destined for the San Francisco financial district were able to use the undamaged Bay Area Rapid Transit system (BART). However trips destined beyond the financial district had to be rerouted to the other bridges that connect the East and North bays to the West bay. The segment was repaired, and the bridge opened to traffic, about one month after the quake (62).

In Oakland, the Cypress Viaduct on I-880, a one-and-a-half-mile long, three-level structure known as the Nimitz Freeway, collapsed over the north half of its length (61). Chunks of concrete fell off in several places. Controversy rages as to who is to blame for the collapses. Some observers blame Californians themselves. A retrofit program designed to strengthen the Nimitz Freeway had not been completed when the quake occurred. The retrofitting program had been divided into two phases, partially due to Proposition 13 (California's landmark tax bill) and budget limits. Phase 1 of the program,

which involved securing sections of road to each other and to support columns with steel cables, had been completed in 1982. Phase 2, wrapping steel wire around support columns, was scheduled to begin this year (26).

The Cypress Street viaduct's age is another factor of interest to observers. The viaduct was constructed in 1957 at a cost of $5.2 million. According to old resources, it required 82,000 cubic yards of concrete and 26,000 tons of reinforcing steel. Though it was build using state-of-the-art techniques, the concrete columns of the viaduct were not built with vertical column reinforcing steel rods (spiral steel) (26).

Impacts of Traffic

Travel patterns were severely disrupted by the collapse or damage to freeway system because of the conditions, many commuters had to switch travel modes. Figure A-1 shows the Bay Bridge corridor travel modes before, during, and after the earthquake (61).

Since traffic on the Bay Bridge had to be rerouted, CALTRANS quickly set up a number of "temporary" HOV facilities on the San Mateo Bridge and the Richmond-San Rafael Bridge. HOV lanes were added to both the eastbound and westbound approaches and to the westbound high-rise section on the San Mateo Bridge. However, since the Bay Bridge reopened, the lane on the high-rise section has returned to operating as a mixed-flow lane. Both approach facilities remain open.

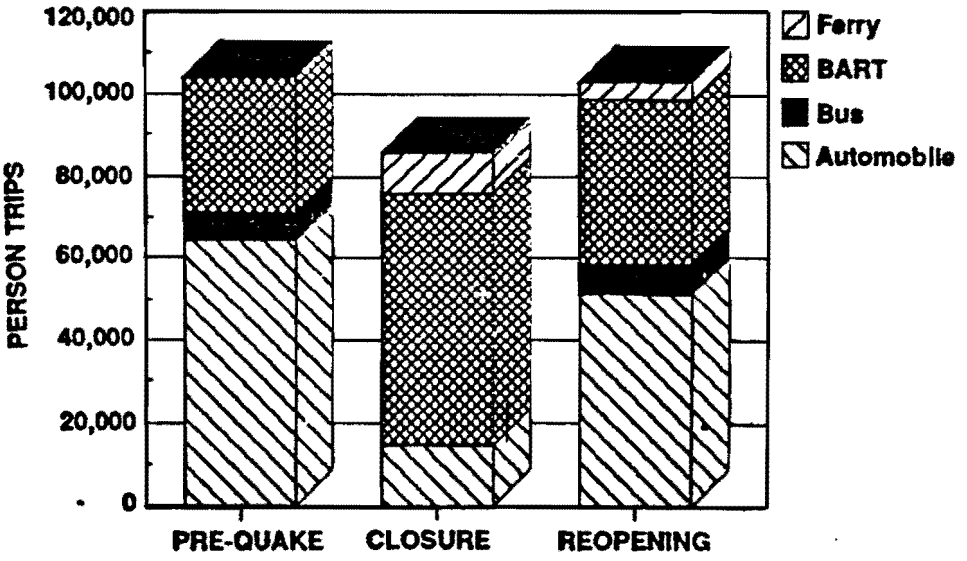

Figure A-1 Bay Bridge Corridor Travel Modes Before, During, and After the Earthquake

After the quake, the full-lane width shoulders of the Richmond-San Rafael Bridge were quickly converted to HOV facilities. The primary approach to the bridge included an HOV lane in both directions. The HOV lanes on the bridge were removed, but the approach lanes are still in operation. CALTRANS has not determined whether the "temporary" facilities will become part of the region's permanent HOV system.

The impact of the earthquake upon traffic extended beyond the damage to the infrastructure components themselves. For example, the Bay Bridge toll plaza before the quake provided HOV users a 10-15 minute travel time savings via three bypass lanes. Since the annihilation of I-880, which is one of three approaches to the Bay Bridge, traffic backs up before reaching the HOV bypass facility, reducing their effectiveness (62).

The Bay Area Transit (BART) system, designed to withstand earthquakes of 8.0 magnitude and greater, came through essentially unscathed. BART, which had more than 350,000 travelers each day (a record) during the month that the Bay Bridge was closed, has retained a substantial number of its new weekday patrons and continues an upward trend (61).

The use of ferries as a means of transportation has also increased. About 6,200 patrons a day were carried by existing ferries before the earthquake. Almost 30,000 patrons were carried at the peak of the bridge closure. The ferry service today still carries double the pre-earthquake level. However, its future still has not been determined (61).

The Oakland International Airport, which opened in 1927, sustained $30 million in damage. A 30-foot sand boil emerged in the airport's main runway. Three thousand feet of the 10,000 foot runway was closed due to cracking from the earthquake and liquefaction of the soil beneath it. Flights into the airport have been accommodated, with the exception of heavily loaded planes (63).

Oakland was somewhat prepared for the events that followed the quake largely because of an August earthquake drill mandated by the Federal Emergency Management Agency that focused attention on, among other things, highway collapses. Communication played a key role in preventing the predicted gridlock following the earthquake. One lesson learned from this catastrophe was the importance of coordination. Good organizational coordination can make emergency procedures run smoothly.

Appendix B: Hurricane Hugo - 1989

In advance of Hugo's landfall, an estimated one-half million people evacuated in coastal areas of Georgia, South Carolina, and North Carolina. Once the hurricane hit land, the storm surge reached 12 - 18 ft, the highest recorded on the east coast this century. The damages were estimated by some sources as high as 7 billion dollars, and over 9,000 homes and 5,200 mobile homes were destroyed (64). Power lines were downed, signals were knocked out, and debris blocked almost all roads. After the hurricane had ran its course, the first priority was to clear all major thoroughfares of debris. The thoroughfares were the lifeline of recovery operations. They were needed to repair power lines, to allow fire and police personnel to rescue people from fallen buildings, etc. A number of questions quickly arose.

- Where do we start?
- Who's in charge?
- Do we have resource and equipment lists available?
- Who's responsible for what?
- Where should supplies and aid from other states go?

South Carolina had prepared for Hurricane Hugo. There had been 101 workshops in the region since the hurricane season had started. There had even been a workshop on September 19th, 1989 just prior to Hurricane Hugo. Officials had a new Emergency Management Plan which was less than 60 days old. Unfortunately, most officials were not familiar with the new plan, and everyone had not yet received it.

On September 20, a hurricane warning was issued to the entire east coast. There was 90 miles of coast lines that had to be evacuated (29). Government officials and agencies met to discuss evacuation procedures, and to allocate for equipment that would possibly be needed during the recovery. News releases were agreed upon, and a list of equipment and supplies that could be moved was developed. With information obtained from the HURREVAC and SLOCH models, officials agreed to ask residents to voluntarily relocate ten hours prior to the announcement of an official hurricane warning (48).

On September 21, at 6:00 AM a hurricane warning was enacted for the entire South Carolina Coast. The Governor issued a mandatory evacuation order for all beach front property. Police officers with bull horns cruised the streets of the island beaches ordering everyone to leave their homes. As shown in Figure B-1, by mid-day, IH-26 was packed with thousands of vehicles heading inland. The trip, normally a two hour ride, was taking up to eight hours for some because of the heavy traffic. Approximately 265,000 people evacuated. At 1:00 pm on the 21st, the Governor ordered all three lanes on IH-26 into Charleston to be converted to outbound traffic (65). Fortunately the traffic started to clear up and it was not necessary to convert the roadway. In addition, the Coast Guard had been alerted to make sure that the draw bridge was not used in order to keep traffic moving (48).

In the aftermath of Hurricane Hugo, most transportation in South Carolina ceased. There were no street signs left and signals were out for five or six days or more. The

WEATHER: Rain and thunderstorms, heavy at times, highs upper 80s, lows in low 70s. Details, 2-A.

FRIDAY, Sept 22 1989

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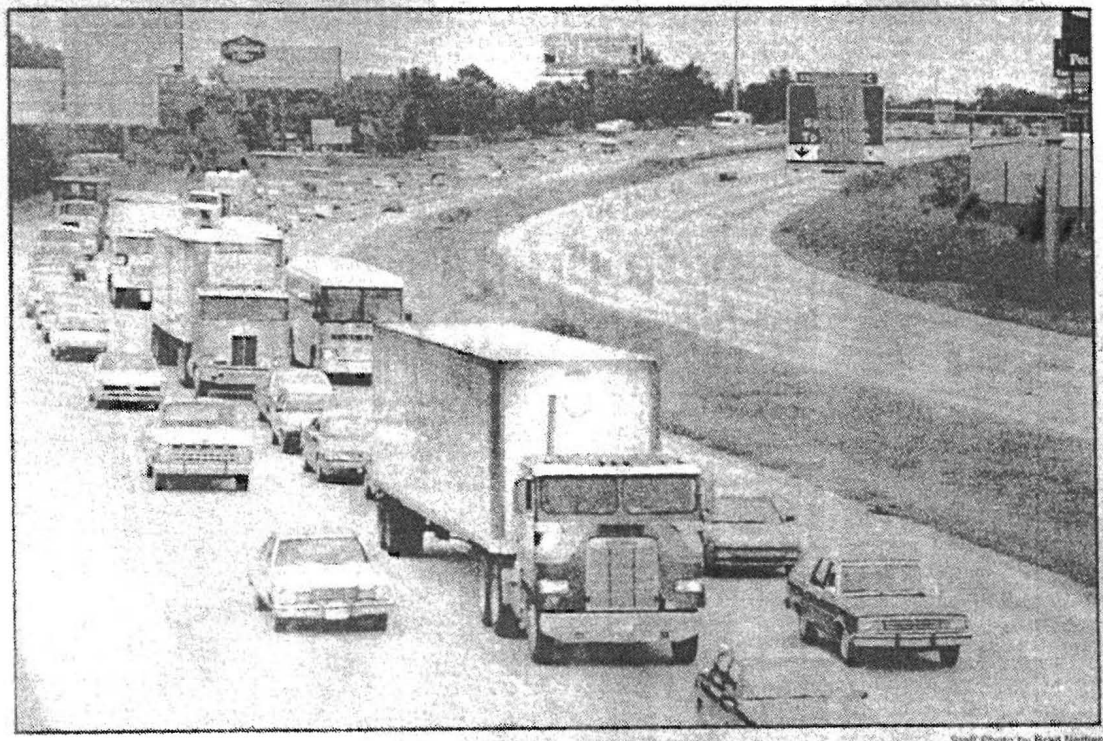

Staff Photo by Brad Nettles

Traffic flees Hurricane Hugo on Interstate 26 as inbound lanes stand empty.

Hurricane evacuees ordered to stay put

By STEVE MULLINS
and JOHN BURBAGE
Of the Post-Courier Staff

Weary clean-up, safety and rescue crews were checking today enormous damage left in the wake of Hurricane Hugo, a storm the size of South Carolina that slammed Charleston with full force, peeling away roofs, downing trees and damaging numerous other structures including City Hall.

North Trident Hospital and a public housing complex on Morrison Drive near the Cooper River bridges were among structures that sustained heavy damage. Patients and staff reportedly were trapped behind collapsed walls at North Trident shortly after midnight, according to unconfirmed reports. Residents were said to be trapped inside the collaped housing project at about 12:30 a.m.

Several houses fell under the strain of high winds and rescue workers were having difficulty reaching inhabitants.

Power lines were down everywhere, gas mains had burst in Charleston and North Charleston, debris blocked roads and rescue workers were having difficulty reaching trouble spots.

The eye of the storm reached the city at about 11:50 p.m. Thursday after winds ranging from 113 to 130 mph raked the area.

The S.C. National Guard and local authorities were ready early today to prevent looting in nearly every community in the Lowcountry, officials said. Reports of looting were reported shortly after midnight in downtown Charleston, and city police were ordered to "take every stick you got" to put a stop to it.

Charleston Police Chief Reuben Greenberg told police, "Don't arrest anybody. Beat 'em. We have no place to put them."

However, the bus carrying police to King Street, where the looting was reported, was unable to get more than two blocks from police headquarters because of flooded streets.

Shortly before Hugo made landfall, Mayor Joseph P. Riley Jr. called a hasty press conference to say the eye of the storm was approximately 10 miles southwest of the city, which put Charleston in the "very worst situation."

Riley said the first priority for today is to clear all major thoroughfares of debris. He said the city

Please see HUGO, Page 7-A

•Games cancelled; tourists stranded; storm photos ... 4-A, 5-A, 6-A, 8-A, 1-B

Figure B-1 Traffic flees Hurricane Hugo on IH-26

signs had to be quickly replaced, as they were essential for the more than 10,000 outside repair crew volunteers that came in to assist in the clean up.

Airports in the Charleston area were shut down for about seven days. However, officials had not stopped people from flying into the region during the evacuation prior to the storm, and people had arrived with no place to go. After a time, an airport official called the airlines and canceled all flights in. In addition, the railroads were also affected by debris, and were shut down for five days (66).

The South Carolina Highway Department was called in to use all available heavy equipment to help clear the roadways. One problem encountered was the need for more electricians. A multitude of power lines were down in the street which were not only dangerous, but they destroyed hundreds of tires on the repair crew vehicles. The tires were finally obtained from an out-of-state business.

Another problem encountered by repair crews was the lack of generators. Generators would have been very useful in restoring power at the critical intersections. In this way police officers would not have to continuously control traffic, as shown in Figure B-2, and could be reassigned to other duties.

In order to restore free movement of traffic, huge amounts of debris needed to be removed. Unfortunately, there was a lack of equipment, and no regional pool or post allocations for such equipment to assist in debris disposal. In effect, there was no way for the donated equipment to get to the appropriate agency.

Figure B-2 Police Officers Control Traffic at Critical Intersection

Another problem identified during recovery activities was the diversity of the debris. There was a lot of mixed debris, and it had to be transported about 20 to 30 miles away. One of the worst problems was with local residents throwing mixed debris into the streets, such as roof shingles (60). In addition, several of the citizens just pushed the debris from their property out on to the right of way so the city would remove it.

A professional hurricane debris removal company hired immediately after the hurricane found that several of the streets were not on the map. Subsequently, FEMA had to come in and reassess the damages, causing a delay in recovery that could have been avoided (60).

Communication proved to be another major problem after the storm. Telephone lines were jammed, and ATT had to reduce the number of calls coming in. Amateur and state radios were available, but it proved not to be a good idea to discuss government agency topics over the public radio (67). Radio and television stations lost power at the transmitting and receiving end, and towers were knocked down. There was only one radio station that had a generator that managed to stay on during the storm.

Eventually, a radio system was donated to officials, and it was put up on 15 frequencies in order to get everybody talking to one another. Communications were kept central throughout the county. This unit is still in use today (56).

Inexperienced volunteers were found to be still another major problem during Hugo's recovery. It was stated that while 13 people died during the hurricane, 26 died during the recovery operations. Most of these deaths resulted from either grabbing a live electrical wire or by fires started by candles.

In summary, some of the lessons learned from Hurricane Hugo were that:

1. There was a need to better inform the officials and the public what FEMA could do for them in times of emergency;

2. There was a lack of communication between government and local agencies;

3. There was a need for better training for interagencies and volunteer staff;

4. There was a need for more advance planning on such issues as: equipment and resource lists, agreements with private companies for equipment such as tires and generators, and regular checks to make sure that all equipment is up to date and in working order.